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Annual Report

of the

Director of the Bureau of Standards

to the

Secretary of Commerce and Labor

for the

Fiscal Year Ended June 30, 1911

WASHINGTON
GOVERNMENT PRINTING OFFICE
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DIRECTOR OF THE BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE AND LABOR,
BUREAU OF STANDARDS,
Washington, July 1, 1911.

SIR: I have the honor to submit the following report of the work of the Bureau of Standards for the fiscal year ended June 30, 1911:

The work of the Bureau has shown steady progress in its various divisions. The number of tests increased to considerably more than double that of the previous year. This growth is due to the steadily increasing interest of the industries in applying scientific data and principles to manufacturing. The great demand for investigations and information has taxed the available force to meet it. A noteworthy feature of the year's progress has been in the investigation and testing of structural materials. The completion of extended investigations affecting the fundamental electrical units and standards is also of special interest.

ELECTRICITY.

On the 1st of January, 1911, the Bureau adopted the new value for the international volt in accordance with the recommendation of the International Committee on Electrical Units and Standards. This unit was adopted at the same time in England, France, Germany, and many other countries, thus securing, for the first time, close international agreement in the measurement of electrical voltage and current. This agreement was reached as a result of the cooperative investigation which was made at the Bureau of Standards by representatives of several national standardizing laboratories, an account of which was given in my report of one year ago. The investigations carried on during this period of cooperation have been continued with a view of further perfecting the official specification of standard cells and the silver voltameter.

ELECTRICAL STANDARDS.

The investigation on the absolute measurement of current, which is of great importance in connection with electrical standards, has

been completed and the results prepared for publication. The object of this research has been not simply to obtain a more accurate value of standard cells in terms of resistance standards and the absolute ampere, but also to develop and perfect the form of ampere balance employed.

The construction of four primary mercurial resistance standards, in accordance with the specifications adopted by the London International Electrical Conference of 1908, has been practically completed.

The data from which the resistance assigned to the four standards are calculated were all determined to a high degree of precision, and the measured differences of the four tubes agree with the calculated differences to within 5 parts per million, indicating the possibilities when the same procedure is followed throughout.

The differences between the Bureau standards and those previously constructed in other national laboratories are somewhat greater, as might be expected.

Two of these laboratories are undertaking the construction of new standards in accordance with the more rigorous London specifications here employed. The comparison of the new tubes with the Bureau tubes will furnish a better basis for estimating the accuracy attainable in the reproduction of the international ohm.

PRECISION RESISTANCE MEASUREMENTS.

This work includes the investigation of methods of resistance measurements, the design and investigation of resistance standards, the determination of the various electrical properties of conductors and the testing of resistance standards, bridges, precision rheostats, potentiometers, etc.

During the past year there has been an increase in the number of resistance standards and other apparatus tested.

Apparatus for the accurate establishment of a resistance ratio of 10 to 1 has been constructed according to the Bureau specifications and now replaces the apparatus formerly used in "building up."

A few resistance standards have been constructed, using a new alloy. While these have been under observation only a few months, the indications are that the new alloy will be found to be as good or better than manganin for use in resistance standards and resistance apparatus.

A study has been made both of resistance standards having four terminals and of the Thomson bridge. The results of this investigation are to be published in the Bulletin of the Bureau.

ELECTRICAL MEASURING INSTRUMENTS.

During the year an extended investigation of direct current switchboard instruments was completed and the results prepared for publi-

cation in order to make the detailed data available to manufacturers and users of instruments. An electrodynamometer capable of carrying currents up to 5,000 amperes has been designed and constructed. A careful study of current transformers and of the methods used in determining their constants has been carried out. The results of this investigation are being published, as are also descriptions of some new types of potentiometers especially designed for the rapid and accurate testing of electrical measuring instruments and for the accurate measurements necessary in electrical engineering. A device for measuring the torque of instruments was designed and constructed and a description of it published. During the year a relatively large number of tests requiring the measurement of torque were made. A standard variable self and mutual inductance was constructed for use in general testing work. Several other investigations have been undertaken in connection with the development of new lines of electrical instruments, and with improvements in existing types.

Upon the renewal of the contracts for supplying light and power to the departments, the Bureau was requested by the various departments, at the suggestion of the Secretary of the Treasury, to test the electric meters measuring the power supplied to the various Government buildings in the District of Columbia.

The tests made during the year included 27 ammeters, 20 voltmeters, 17 wattmeters, 94 watthour meters, 3 power-factor meters, 15 current transformers, 20 insulation tests with high voltage, 2 arc lamps, 33 electric fans, 19 dry cells, and 4 miscellaneous tests—a total of 269 pieces.

ELECTRICAL RESISTIVITY OF COPPER.

The results of the investigation to determine the electrical conductivity and temperature coefficient of average commercial high-grade copper were published during the year. A reasonable agreement was found for samples from different sources, and satisfactory average values were obtained. The measurements were made with an unusually high accuracy, which was made possible by a specially designed and constructed apparatus. It was discovered that the temperature coefficient and conductivity are substantially proportional. This relation has been corroborated by work done at the Reichsanstalt, of Germany, and has a number of useful consequences. It was also found that bending and winding do not change the temperature coefficient, and consequently the internal temperature of dynamos and instruments may be calculated from resistance measurements with greater confidence than heretofore. The results of this investigation are the basis of new standard values for the conductivity and temperature coefficient of copper which it is expected will soon be adopted internationally. A circular has been prepared containing informa-

tion about wire gages, etc., and a complete set of copper wire tables. The tables have been adopted as the official wire tables of the American Institute of Electrical Engineers, replacing their old Wire Table of 1893. The Standards Committee of the American Institute cooperated with the Bureau by suggesting the investigation and by their advice and criticisms in the preparation of the circular. The Standards Committee and the Bureau have also cooperated in the consideration of such questions as electric cable standardization, and the definition and value of the horsepower.

MAGNETISM.

A series of samples of transformer steel have been exchanged among the several national laboratories for the purpose of comparing the methods of core-loss measurement. The resulting data show that the various laboratories and methods now yield results that do not differ by more than 1 per cent.

A series of rods for use in comparing the methods of measurement of normal induction and permeability are being exchanged in the same way, and while the data thus far obtained show that greater variations exist the differences are not excessive. These intercomparisons are bringing to light heretofore unnoticed sources of error, and future intercomparisons will undoubtedly show closer agreement.

Much attention has been paid to the methods of commercial testing. In cooperation with the Committee on the Magnetic Testing of Iron and Steel of the American Society for Testing Materials, considerable progress has been made toward the standardization of the methods of magnetic testing in commercial laboratories. For the core-loss measurement agreement has been reached as to the size of the specimen and all the details of apparatus and procedure to be used in commercial testing; for permeability measurements the details of specimens and apparatus are not defined, but the general method has been agreed upon.

A number of magnet steels obtained from various sources both in this country and abroad have been studied and their relative values for use as permanent magnets investigated. This is part of the general plan to accumulate data on the magnetic properties of all the commercial steels.

Data are being collected on the relation between the magnetic and mechanical properties of commercial steels with a view to finding some simple magnetic test which may supplement or replace some of the mechanical tests and thus avoid the destruction of the material under examination.

ELECTRICAL TESTING.

The amount of electrical testing for the past year has exceeded that of any previous year. The following instruments and materials have been tested:

For State and National institutions and for the public, exclusive of the testing done for the other divisions of the Bureau, 78 resistance standards, 5 resistance bridges, 5 potentiometers, 58 standard cells, and 6 miscellaneous pieces of resistance apparatus have been tested and the electrical properties of 35 samples of conductors determined.

Under the head of inductance and capacity measurements 104 pieces of apparatus have been tested, including wave meters; self and mutual inductances, both constant and variable; condensers, in which the direct current and alternating current values are sometimes determined separately (temperature coefficient and absorption also being determined in addition to the capacity); and the residual capacity of resistance coils—the total number of tests amounting to 325.

In the section of electrical measuring instruments there were tested 27 ammeters, 20 voltmeters, 17 wattmeters, 94 watthour meters, 3 power factor meters, 15 current transformers, 20 insulation tests with high voltage, 2 arc lamps, 33 electric fans, 19 dry cells, and 4 miscellaneous tests—a total of 269 pieces.

In the magnetic laboratory 46 samples have been tested for core loss, 26 samples for normal induction and hysteresis, and 8 miscellaneous tests were made on magnetic standards and induction coils.

PHOTOMETRY.

In the photometric section the work is divided into three parts, as follows: First, the preparation and testing of photometric standards and the intercomparison with foreign laboratories of the primary standards with a view to maintaining the international standard of candlepower; second, the photometry of gas standards and the testing of various kinds of sources of illumination; third, the inspection and testing for candlepower efficiency and life of incandescent electric lamps purchased by the various Government departments.

During the year a large amount of work has been done in making a thorough intercomparison of our primary standards and in the preparation and study of new standards especially of different makes of drawn-wire tungsten filament lamps. Considerable time has been given to a study of the precision of photometric measurements and of the reproducibility and constancy of electric incandescent filament photometric standards. Sixty-five carbon and 25 tungsten standards have been furnished to the various bureaus of the Government or sold to the public; and in addition, 96 carbon, 32 tantalum, and 80

tungsten lamps have been standardized, making a total of 298 standards of all kinds.

Up to the present time the international unit of candlepower has been maintained entirely by means of carbon filament lamps. The advent of the tungsten and other high-efficiency lamps has made it highly desirable to have high-efficiency primary standards also, because of the difficulty of comparing light sources of different color. In order that the international unit may be properly maintained at the higher efficiency, we have agreed with the National Physical Laboratory of England to interchange a number of tungsten lamps standardized at about 1½ watts per candle efficiency. These lamps have been selected and are being carefully prepared for this purpose.

In connection with the inspection and life testing, 944,000 lamps have been inspected by the traveling inspectors of the Bureau, who inspect lamps at the factories and take samples for life test at the Bureau; 3,843 of these samples have been tested at the Bureau for candlepower and life. The result of this work is to enable the Government to buy lamps on specifications and to assure itself that the lamps delivered meet the standard of the specifications. It also has a tendency to standardize the output of the manufacturers and to improve the quality of the lamps furnished to the public.

The work on flame standards of candlepower was continued and a satisfactory determination of the effect of atmospheric conditions on those standards was completed. This work has an immediate practical application in the improvement of the methods of testing illuminating gas. The results already obtained and published have contributed to the progress which is being made in this line in many cities, and have given rise to much correspondence in which the Bureau has been able to furnish information based on our experience with these standards. Another result of the interest aroused in accurate methods of gas testing has been an increase of 100 per cent over the preceding year in the number of flame standards submitted for test. A large amount of time has been expended in the collection of information regarding other details of the inspection of the gas service in cities and towns of all sizes, for the purpose of combining the best features of present practice in a circular of information which may serve as a guide for local authorities in drafting regulations.

The legislative regulations for locomotive headlights proposed or enacted in several States led to a large amount of work on the part of the Bureau in making measurements of various types of headlights to obtain data on which a fair interpretation of such regulations could be based. Considerable time was given also to measurements of arc and gas lamps used in the parks of the District of Columbia, with the result that modifications have been made in the street gas lamps

of the District, which increase the light produced by 50 per cent without any additional cost to the Government.

Four portable photometers were calibrated, three being for Government or municipal officers, and a number of special lights were measured for manufacturers.

INVESTIGATIONS IN ELECTROLYSIS.

During the past year an extensive investigation into the subject of electrolysis has been in progress. This subject is one of great practical importance, not only to engineering interests, but to municipalities and the general public. Damage to water and gas pipes and other underground structures by stray electric currents has long been a source of serious trouble, and although much work has been done by private interests with the view of mitigating the evil a great deal of investigational work remains to be done before remedial measures can be applied with satisfactory precision. Also during the last few years a great deal of attention has been drawn to the possibility of damage to reenforced concrete structures, due to stray currents, and much alarm has been created in some quarters lest great damage to buildings, bridges, etc., may result from this cause. Although the possibility of damage of this sort had been established, little was known before this investigation was started in regard to the extent of the damage that had occurred, the conditions under which trouble might be expected, or the best method of mitigating the evil.

The present investigation was undertaken in response to requests from important engineering interests, and in carrying out the work the Bureau has had the hearty cooperation of many engineers, corporations, and municipalities, they in some instances undertaking considerable expense in order to assist the Bureau in making the investigations. During the last half of 1910 the work was confined mainly to investigations relating to electrolysis of reenforced concrete, owing to limitations of equipment and personnel, but early in the present year the work was broadened to include investigations into the general subject of electrolysis, particular attention being given to methods of preventing trouble from this source. A great deal of valuable information has already been obtained, but much important work remains to be done, and it is planned to continue the work during the coming year.

WEIGHTS AND MEASURES.

The work of the division of weights and measures consists of the custody and maintenance of the standards of length, mass, volume, density, etc., keeping these standards available to the public, and compiling and distributing information relative to them. It has also

for one of its objects the general improvement of weights and measures conditions throughout the country.

LENGTH AND EXPANSION MEASUREMENTS.

During the year experiments have been made to secure data for use in designing apparatus to control temperatures in length measurements. Valuable information was obtained from a study of the influence of various conditions on the linear distribution of the temperature of the air within a jacketed cylindrical tube heated by oil circulating between the tube and its jacket. This arrangement proved to be a simple and satisfactory means of securing great uniformity of temperature in long specimens. During the latter part of the year the thermal expansivity of 25 different specimens was determined for temperatures ranging from −25° to +172° C and it is planned to considerably extend this range in the final comparator. In the work referred to above, the temperatures were measured with a copper-constantan thermoelement whose equations and curve were deduced from potentiometer observations of the electromotive force when one junction was in melting ice while the other was successively in a mixture of solid carbon dioxide and gasoline, in steam, and in the vapor of boiling naphthaline.

During the year about 240 length measures of various kinds were tested, somewhat less than half being for either the Federal or State Governments. Those for the Federal Government included invar tapes for the Coast and Geodetic Survey and the United States Geological Survey. Other length-measuring apparatus tested for the Federal or State Governments included level rods, paper micrometer gages, and standard yards and meters for States. Of the length measurements made for others, the major part were steel tapes for surveyors and constructors, though no inconsiderable part of the work came from municipalities whose interest in the inspection of the weights and measures used in trade has been stimulated by the conditions found in the investigation by the Bureau of weights and measures conditions throughout the country.

The equipment for length measurements has been added to by the purchase of an invar meter bar having approximately the coefficient of expansion of platinum, with the graduations ruled on a platinum strip inlaid in the bar. Apparatus for determination of expansivity has also been developed and tested. Some improvements have also been made in the apparatus used for calibrating length standards.

A number of check measurements have been made on the working standards used in the length work, and considerable progress has been made in the more accurate calibration of the bench standards used in the steel tape comparison.

CAPACITY MEASURES.

The number of metal capacity measures tested during the year was more than double that of the previous year, about one-fourth being for the Federal or State Governments. Those for the Federal or State Governments included standards for Porto Rico, the Panama Railroad, and the States of Wisconsin and Alabama. Standards were also tested for several city governments and manufacturers. A number of cubic-foot bottles, for use in testing gas-meter provers, were also tested.

About 9,000 pieces of volumetric glassware were tested during the year, practically all of it being for the Federal Government.

MASS.

The number of tests of weights more than doubled during the year, and, in consequence, it was impossible to give the tests as prompt attention as could be desired. This applies particularly to tests for those States which are now preparing to establish weights and measures inspection departments for the protection of the purchasing public and those merchants who desire to conduct their business on an honest basis.

By act of Congress, the old troy pound of the mint at Philadelphia was superseded by the standard of the Bureau, and for all purposes in the United States there is now a single standard of mass. This in no wise changes the actual value of the mint weights, but substitutes the platinum-iridium kilogram for the old brass mint pound as the fundamental standard.

DENSITY.

Several very important density determinations were completed during the last year. That on the density and thermal expansion of ethyl alcohol and its mixtures with water will soon be published and should prove a valuable contribution to those industries engaged in the production of alcohol or to those using it. Work on the density and thermal expansion of linseed oil and turpentine was also carried on. Tables were computed for obtaining the density of linseed oil at any temperature between 10° and 40° C from its density at any other temperature within the same range.

Tables were also prepared for converting from pounds to gallons, and vice versa. The investigations were undertaken at the request of the American Society for Testing Materials and others interested.

The number of hydrometers tested during the year exceeded 2,400, most of them being alcoholometers for the Internal-Revenue Service.

TIME.

In August, 1910, a direct wire to the United States Naval Observatory was installed for the transmission of the noon signal. The

previous use of the noon signal as transmitted by wireless telegraph had proven unsatisfactory, partly by reason of the irregularity with which it was sent from the wireless station and partly because of the lack of suitable instruments for recording it.

At the request of the Supervising Architect of the Treasury Department the Bureau made a comparative test of a number of different systems of master and secondary clocks suitable for installation in public buildings, the test covering a period of six months. The various makers were invited to submit a set of their clocks, and the systems of the six makers who accepted the invitation were installed the latter part of July, 1910. Daily comparisons of the clocks were made to determine the uniformity of rate of the master clock and to note any irregularity in the performance of the secondaries. The clock movements were examined and rated as to workmanship, and estimates were made of the cost of maintenance of the various systems.

These results, together with other tests and examinations of the operation and reliability of the systems as a whole, were reported to the Supervising Architect and will be used by him in awarding contracts for the installation of clock systems in Government buildings.

ANEROID BAROMETERS.

A study of the sources of error in aneroid barometers has been undertaken in connection with the development of standard methods for testing. A thorough investigation of mechanical accuracy, elastic lag, temperature compensation, and permanence is necessitated by the fact that under different conditions a commercial aneroid of the best quality may differ by several per cent in its indications of a given pressure change.

Experiments which have already served to determine qualitatively the various sources of error and their relative significance will be supplemented by an intercomparison of representative aneroids of different types and sizes to be furnished by makers and dealers who have expressed their desire for cooperation.

The investigation has for some time been urged by manufacturers. They desire to see established a method of testing which will make a proper distinction between defects of workmanship and errors physically inherent, as well as a uniform and authoritative system of certifying and rejecting. The work is of no less importance to the public, for all who must use aneroid barometers are at a loss to know with how much confidence the corrections obtained in the laboratory may be applied under the diverse conditions of practice. The increasing dependence of aviators upon aneroid altitude measurements adds to the present importance of the problem.

TRADE WEIGHTS AND MEASURES INVESTIGATION.

The investigation of trade weights and measures conditions throughout the country, for which Congress made special provision, has practically been completed and will form the subject of a special report. Every State in the Union, with the exception of Arkansas and Oklahoma, has been visited, and inspections in the two mentioned will be made early in the coming year.

During the two years that this investigation has been in progress 8,630 scales have been tested, of which 3,607, or 41.8 per cent, were incorrect. The total number of weights tested was 10,929, of which 2,231 were incorrect. The number of dry and liquid measures tested was 6,088, of which 2,018, or approximately 33 per cent, were incorrect. Of the incorrect apparatus found, a large proportion of it discriminated against the consumer and, consequently, furnished the strongest argument for the establishment of inspection services by the States. The investigation has attracted the widest attention and has resulted in the enactment by the States of either laws to render efficient the old weights and measures laws or else entirely new laws. During the year the legislatures of 35 States gave consideration to bills to either establish weights and measures laws or amend those already on the statute books, and 25 States passed important legislation on the subject. The indications are that all the States are thoroughly alive to the importance of the matter and that in a few years every State in the Union will have provided means to guarantee the integrity of the weights and measures used in trade.

To insure uniformity in the State laws, a model law was drafted by the Bureau, and this law, with minor modifications to suit local conditions, has been adopted in a number of the States. The Bureau also drafted a model weights and measures ordinance for municipalities, for which there was urgent demand. A list of apparatus suitable for State and city sealers was also prepared in response to numerous requests for advice as to the proper equipment for such officials. The Bureau has also rendered aid to the States in the establishment of their inspection departments, sometimes by detailing an expert in the work and sometimes by correspondence.

An investigation to determine the variation in the weight of food products put up in package form, with time and under different atmospheric conditions, was conducted with a view to securing information of value in establishing tolerances on the net weight or measure of manufactured food products put up in packages. A large number of the more common articles, such as cereals, crackers, dried fruit, etc., were purchased and divided into three lots, the first of which was kept in a room at normal temperature and humidity, the second in a room where the air was quite moist, and the third in

a room where the air was quite dry and at a high temperature. Weighings were made at regular intervals, and the temperatures and humidity were also observed. The results will be of great value in establishing permissible variation in the weight of such commodities in case a net-weight law is passed by Congress, and they will also be of much assistance in answering many questions that will arise in the consideration of such a possible law.

The time has now arrived when the power granted to Congress to fix the standard of weights and measures, by paragraph 5 of section 8 of Article I of the Constitution of the United States, should be exercised.

The practice of selling by gross weights, which enables the manufacturer to deliver an unknown amount; the selling of manufactured food products in packages; the development of transportation facilities, which has greatly increased the shipment of fruit and vegetables from one part of the country to another, have created a demand for the standardizing of packages, barrels, boxes, crates, baskets, etc., that can only be met by national legislation. The attempt to correct some of the evils by State legislation, which compels the merchants doing an interstate business to conform to different requirements for different States, has only complicated the situation. What is needed is—

1. A national law defining and fixing the usual weights and measures that may be used in everyday trade.

2. A law fixing the sizes of the more common shipping units, such as barrels, bales (of cotton), boxes, baskets (fruit), etc.

3. A law requiring the net weight, measure, or numerical count to be plainly stated upon the outside of all commodities put up in sealed packages.

Also a law to eliminate the manufacture and sale of apparatus designed to facilitate fraud.

Briefly, the provisions of such bill should also require each manufacturer of commercial apparatus in the country to submit a sample of the various types of scales, weights, and measures made by him and sold for commercial use; to empower the Bureau of Standards to examine and test such apparatus as regards type, and thus to determine whether the type is a satisfactory one and does not facilitate the perpetration of fraud, the Bureau to issue certificates for such type of apparatus conforming to certain standard specifications, which certificate would allow the manufacturer to manufacture and sell throughout the country such certified apparatus, and, finally, to require that no apparatus failing of certification by the Bureau may be manufactured and sold in the United States.

Such a law would be of great assistance to the manufacturers in making a standard product, and would avoid the necessity of each

State establishing regulations, which are certain to lack uniformity. It would, furthermore, be a great help to the local officials in eliminating fraud in commercial dealings, and would, it is believed, tend to greatly improve existing conditions. It would also be a protection to the merchants, since they could feel assured that any apparatus purchased for commercial use by them would be of satisfactory construction.

THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

The work of this division is primarily the maintenance of a standard scale of temperature always available to the public for reference, and, secondarily, the making of tests and the investigation of problems of all sorts in which accuracy in the measurements of temperatures is essential.

THERMOMETRY.

A total of 18,693 thermometers were tested during the year, made up as follows: 236 ordinary calorimetric thermometers and 49 Beckmann calorimetric thermometers, graduated to 0.01° or 0.02°, for use mainly on the determination of the heating values of fuels; 965 laboratory and special thermometers for the general purposes of temperature measurement in the interval —30° to 500° C; 17,431 clinical thermometers, for the use of physicians, and 12 sterilization (melting point) thermometers.

Work was continued during the year on the calibration of a number of primary standard mercurial thermometers, made of different glasses, for use as standards in the interval 100° to 500° C.

Electrically heated oil bath and copper block thermometer comparators were designed to facilitate the testing of thermometers in the interval 100° to 500° C, with the highest accuracy, and were constructed in the instrument shop of the Bureau.

An investigation was completed and published during the year on the reproducibility (0.03° to 0.05°) of the sulphur boiling point (444.7°), its use as a fixed point for the calibration of platinum resistance thermometers, with a discussion of the temperature scale defined by means of such thermometers calibrated at the temperatures of melting ice, steam, and sulphur vapor, which is the method used to define the standard temperature scale of this Bureau in the interval 100° to 500° C. The remarkable agreement of the scale so defined with the scale of the gas thermometer and with the absolute scale, as indicated by some work only recently completed and published abroad, would seem to lend hope that international agreement may soon be reached on the standard scale of temperature above 100° C., such as now obtains in the interval 0° to 100° C.

The work of designing, constructing, and testing the apparatus needed in the repetition of the Joule-Kelvin porous plug experiment has continued with some interruptions.

A critical account of two methods of determining the stem correction of the mercurial thermometer, supplementary to the information given in Bureau Circular No. 8, has been prepared and will be published shortly in the Bulletin.

Bureau Circular No. 8, giving information on the construction, use, and testing of mercurial thermometers, and Circular No. 5, giving similar information relating to clinical thermometers, have been revised and enlarged and are now in press.

CALORIMETRY.

During the year the necessary preliminary work on the determination of the heats of combustion of napthalene and benzoic acid was completed, so that samples of these substances, with certified values as to the heat of combustion, have been issued. Standard sugar has been supplied as heretofore, but with the thermal constants determined in this laboratory. Bureau Circular No. 11, on the standardization of bomb calorimeters, has been issued to accompany the samples and to furnish information to users of these instruments for the testing of the heat values of fuels. Considerable work was done on methods of purifying the above-mentioned materials and on the determination of their heats of combustion when purified in different ways, as a basis for certification.

There were sent out during the year 93 standard combustion samples, which were used by chemists and engineers for the standardization of their calorimetric apparatus. The introduction of these standard samples has already done much to increase the accuracy of and to reduce the results of fuel tests to a uniform and comparable basis.

Incidental to the determination of the water equivalents of the calorimeters, used in the above work, by electrical methods, a series of determinations of the water equivalent of the calorimeter without the bomb were also made. From these a series of values of the mechanical equivalent of heat, J, based on the electric units is readily calculated. A series of values were thus obtained consistent to 1 in 10,000. Some further work should be done before publication of final results.

A new calorimeter, the important features of which are arrangements to define, as closely as possible, the limits of the calorimetric mass, combined with convenience in manipulation, has been designed and was constructed in the instrument shop. The outer water jacket has provision for electric heating and thermostatic control, as well as means of working according to the adiabatic method of Richards.

A new wheatstone and double-Kelvin bridge for use with resistance thermometers was completed and is now in use. Some improvements in the B. S. type of calorimetric resistance thermometers have been made and one firm of instrument makers has undertaken their manufacture. A number of these thermometers have been standardized for outside users. A new type of slide wire bridge for use with these thermometers was outlined and is now being made by the same instrument makers. Installations of this kind have already been adopted by one of the bureaus of the Government and by other laboratories.

In connection with the calorimetric work on standard combustion samples it became necessary to have pure oxygen in large quantity and under high pressure. A very complete plant for this purpose has been designed and constructed and is now installed.

A considerable amount of work was done on the determination of the efficiency of commercial gas calorimeters, as well as on the intercomparison of different types. Some work was also done, incidentally, to determine the most reliable methods of testing the gas meters used with these calorimeters and on the accuracy attainable with such meters.

PYROMETRY.

The high-temperature tests may be summarized as follows: 28 thermocouples, 12 pyrometer galvanometers, 3 Fery total radiation pyrometers, 1 Wanner optical pyrometer, and 8 platinum resistance theremometers, for the measurement and control of high temperatures in various industrial operations; 1 electric resistance furnace; 21 melting point determinations of fire bricks, refractories, blast-furnace slags, and alloys; 12 Seger cones; the fire-resisting qualities of 4 samples of brick and terra cotta; and the heating and cooling curves of a number of steels of different composition.

In addition to the tests enumerated above, several tests were made in the works with a view to demonstrating the application of various pyrometric methods to industrial problems. Among these may be mentioned the measurement of the temperature in a large copper converter at the Baltimore Copper Works, by means of optical pyrometers; the measurement of the temperatures of molten steel when tapped from the furnace, when being poured into the molds, and the temperature of forging, at the Firth-Sterling Ordnance Works. Simultaneous measurements with thermoelectric and optical pyrometers gave as a preliminary value for the emissivity of molten steel for red light $e_{red}=0.4$.

Considerable work was done during the year on the calibration of a number of new pyrometer lamps and thermocouples for use as the high-temperature standards of the Bureau.

The existing data on the melting points of the chemical elements have been collected and digested and will be published in the near future as a circular of information.

A large amount of work has been done on the determination of the critical points of steels, from the so-called heating and cooling curves, using different methods of observation. A special vacuum furnace has been constructed for this work, with automatic control of the rate of heating. A series of carbon steels of known composition were kindly furnished for this work by Prof. H. M. Howe, a member of the visiting committee of this Bureau. It is hoped to extend this work to other special steels, pure iron, etc., with a view to determining the effect of rate of heating, of the surrounding atmosphere, and of the size and heat capacity of the specimen on the location of the critical points.

Methods have been developed for the determination of the melting points of refractory materials by means of heating curves taken on the specimen as it is heated in a vacuum electric furnace, the temperatures being measured with an optical pyrometer. The methods have been applied to a number of refractory oxides and minerals, to clay, magnesia, bauxite, silica, and chromite fire bricks, and to blast-furnace slags, etc.

Most of the necessary apparatus, including a large vacuum electric resistance furnace, has been constructed for the determination of the thermal conductivities of commercial refractory materials at high temperatures.

An improved method of computing the constant C_2 of Planck's radiation equation from observed energy curves was devised by a member of the division in collaboration with a member of the electrical division and has been published in the Bulletin.

There is considerable demand on the Bureau to furnish materials of known melting points, i. e., standard temperature samples, similar to the standard combustion samples now furnished, to enable users of high-temperature measuring instruments to obtain a convenient check on their accuracy from time to time. Some work has already been done, with this end in view, on the reproducibility of the melting points of metals and salts obtained from different sources.

As soon as the necessary assistance can be provided, the determination of the thermal conductivities of materials used for the purposes of heat insulation should be undertaken. The great importance of this problem has been strongly emphasized by the refrigeration industries.

Owing to the great increase in the work of testing, little or no progress has been made during the year on some important investigations relating to the establishment of the standard temperature scale. It is earnestly hoped that the necessary assistance can be provided to

take care of the testing work so that the men who are especially trained for these investigations may carry them to an early conclusion.

MISCELLANEOUS.

Other tests carried out in this division were as follows: The freezing points of 5 solutions of calcium chlorides of different concentrations; 3 thermographs; the flash points and viscosities of 27 samples of lubricating oils.

An important feature of the work of this division is the correspondence carried on with many technical and scientific men, and relating to the applications of thermometers, pyrometers, and calorimeters to industrial and scientific problems.

A large number of intercomparisons were made between the Engler, Saybolt, and Redwood viscosimeters, as a result of which it is hoped to publish transformation tables to enable technical men to express the results obtained with any one instrument on the scale of the other two.

A course of lectures by a member of this division, given at the request of the Navy Department before officers of the School of Marine Engineering at Annapolis, led to a study of certain points in steam turbine design and to the development of a convenient practical method for determining the reheat factor. The results, which will appear in the Bulletin, were published in condensed form in Vol. XXIII, No. 2, of the Journal of the American Society of Naval Engineers.

One of the members of this division gave a lecture before the scientific staff of a large manufacturing plant on recent developments in the field of high temperatures, and contributed a paper to one of the large technical schools on the relation of the work of this division to the public.

OPTICS.

During the year important researches were made in this division, which includes radiometry, spectroscopy and applied optics, polarimetry, and interferometry. These researches supplement other methods for determining the physical constants and properties of materials, and are very valuable for this purpose. Besides conducting the researches, many optical tests have been made for the Government and the public, such as telescopic and photographic lenses, prisms, samples of glass, polariscopic apparatus, and sugar analyses.

RADIOMETRY.

During the year work was continued on the radiation constants of a complete radiator, using as a source of radiation a uniformly heated inclosure—the so-called "black body"—which gives a somewhat lower value of the radiation constants than was previously obtained.

The results of investigations made of this subject during the past three years are being prepared for publication.

The increased refinement demanded in the investigation of instruments and methods used in radiometry has resulted in the production of a steadier and more reliable radiometer. During the past four years various bolometers, thermopiles, and radiomicrometers have been constructed and tested on various researches. The latest attainment is a spectroradiometric outfit consisting of a vacuum bolometer, a storage battery and a galvanometer, which for speed, steadiness, accuracy, wide range of variation in sensitivity, and convenience in operation, stands unique. The results of the above investigations and the latest attainments of various other experimenters are being prepared for publication.

An account was published of an investigation of the selective absorption and emission of the acetylene flame, and of the selective emission of the Welsbach gas mantle and of the same material when formed into solid rods and heated electrically. It is shown that the peculiarities of these two types of illuminants can be explained on a purely thermal basis. This is the third paper issued on the selective radiation of various substances, and the investigation is to be continued.

An investigation was completed on light filters (solutions) which have a high transmission in the visible spectrum and absorb all the infra-red rays; also an investigation of substances (opals) containing water of crystallization. This is really a new method for the investigation of the condition of water in minerals. The radiometric test finds no distinction between "water of crystallization," "dissolved water," and "water of solid solution," all giving the absorption spectrum of water in its free liquid state. The results of these investigations will soon be ready for publication.

The investigation of the various types of radiometers for measuring radiant energy in absolute units has been continued, with a view to the development of a standard instrument. None of the instruments thus far investigated fulfills the requirements of a primary standard.

These radiometric investigations are of fundamental importance in connection with the various determinations of the properties of materials. Many are undertaken as a result of requests for information which is not in existence, as, for example, the light filters, which were desired by psychologists desiring intense luminous stimuli free from infra-red radiation.

POLARIMETRY.

Excellent progress has been made in the various polarimetric investigations during the past year, in addition to equipping the new quarters devoted to this work. The determination of the 100° point

of saccharimeters—the most important problem at present in saccharimetry—has been continued. Throughout the sugar and sirup industries, the saccharimeter is the fundamental instrument in standardization. As a requisite of this work, sugar of the highest purity has been prepared from the widest possible variety of sources. This problem has also necessitated further study of intense sodium light sources.

The installation of the large electromagnet has been completed and it is now in use. This instrument was installed for the purpose of studying the peculiar effect of magnetism upon light waves, twisting their plane of vibration and changing their lengths.

A number of improvements have been made in the new type of polariscope designed at the Bureau, the most important being an auxiliary fine adjustment to make available the full sensitiveness of the instrument for especially accurate work. Its many superior features have caused a wide commercial and scientific demand for this instrument.

The testing of sugar and sirup samples for the Treasury Department, to check the analyses made at the larger customs laboratories, has been continued. The differences between the results obtained at these laboratories and at the Bureau have been reduced to below 0.2 per cent—the closest agreement yet attained.

The demand for samples of sugar of highest purity, for standardizing polarimeters and calorimeters, has increased considerably, and 85 samples were supplied during the year. The preparation of these samples will be of great value to the industries, since the heat value of fuels is determined upon the standard basis established by them. In addition to the above, 1,351 polarimetric tests were made.

SPECTROSCOPY AND APPLIED OPTICS.

Conducting helium gas has been further investigated in regard to suitability for furnishing a primary light standard with good results as regards reproducibility of color and intensity. A spectroscopic study of the causes of deterioration in certain commercial vacuum bulbs is in progress. A number of vacuum tubes of special form filled with gases of certified purity have been prepared upon request.

A number of photographic objectives, reading microscopes, oculars, and field glasses have been tested for the Government and for dealers. Methods of testing have been further developed. A circular of information has been issued, dealing with optical instruments.

A great many determinations of refractive indices have been made and refractometer test plates standardized. A number of the best refractometers have been added to the equipment. A set of prisms for secondary standards has been prepared.

Tests of absorption made during the year include blocks of optical glasses, standard absorbing screens for manufacturers of smoke-testing instruments, and the spectral absorption of numerous optical glasses designed to protect the eye from injury by ultra-violet radiation. A circular of information dealing chiefly with absorbing materials has been prepared and published.

Tests made include coefficients of diffuse reflection of wall coverings and the spectral reflection of optical papers. A new method for the absolute determination of the coefficient of diffuse reflection has been devised and developed.

In colorimetry the wave length of the dominant hue and the per cent white impurity in a number of secondary color standards have been determined. A new form of colorimeter for making such absolute determinations has been designed and is being constructed. A new instrument for determining the constants of the natural-color scale has also been designed.

Investigations of the size, shape, and distribution of the grains in photographic plates in relation to resolving power, definition, and halation and the effect of exposure and development have been continued.

In physiological optics, work has related chiefly to color sensibility and the injurious effect of ultra-violet light on the eye.

INTERFEROMETRY.

The determination of relative wave lengths of light has been continued. A table of 10 wave lengths in the spectrum of neon has been completed. Experience has shown that the neon lamp will be especially useful in interference measurements, and it is thought that its extended use will increase the practical applications of such measurements. The new table will be of use in this connection, as well as in spectroscopy where the wave lengths are needed as reference standards. Preliminary arrangements have been made for determining coefficients of expansion by interference methods.

CHEMISTRY.

The following research problems have been completed during the year and the results have either been published or are being prepared for publication: A convenient potash bulb; the action of sunlight and air upon some lubricating oils; the behavior of high-boiling mineral oils on heating in air; the determination of total sulphur in india rubber; the influence of added fatty oils, etc., upon the carbonation of mineral lubricating oils; the determination of vanadium in vanadium and chrome-vanadium steels; the determination of manganese in vanadium and chrome-vanadium steels; the determination of chromium in chrome and chrome-vanadium steels; the determina-

tion of manganese by the sodium bismuthate method; the density and thermal expansion of ethyl alcohol and of its mixtures with water in collaboration with the division of weights and measures; the theory and use of the silver voltameter in collaboration with the electrical division; a new apparatus for vacuum sublimation; and apparatus for the preparation of pure oxygen on a large scale.

The following are some of the lines of research work in progress: Testing of monel metal as to its value for many forms of laboratory utensils and appliances that are now made mostly of iron; the testing of sodium oxalate to be used as a primary standard in the determinations of iron, manganese, and other substances; analysis of phosphate rock, preliminary to the issuing of this material for checking analytical methods; the chemistry of the silver coulometer; the preparation of pure organic substances for calorimetric work; the preparation and purification of materials for the mercury-cadmium cell; the atomic weight of bromine; the composition of the printing inks used at the Government Printing Office; study of gas-testing methods; study of underground electrolysis, in cooperation with the electrical division; paper research problems; investigation of the value of various materials used as waterproofing, damp proofing, and roofing coatings; and a study of the resistance to corrosion of the various types of ferrous metals.

One of the members of this division is chairman of a committee of the American Society for Testing Materials having in charge an extended series of service exposure tests of white pigments, in which the Bureau will cooperate. Another member is chairman of a committee of the American Chemical Society charged with an investigation of the quality of laboratory utensils of platinum. The Bureau cooperates in this work by placing facilities and material at the disposition of the committee.

Several members of this division devoted much time during the year to assisting the President's Commission on Economy and Efficiency to draw up systematic schemes of classification for chemical supplies and apparatus.

Of the Bureau's series of analyzed samples there were issued, on request, 1,209 irons and steels and 274 ores, a total of 1,483, over double the number issued for the previous fiscal year. The large increase was in part due to the demand for the four iron-ore samples which became available for distribution during the year. The continued and increasing demand for these samples and for others not yet ready fully justifies the Bureau in adding to its list. The experience gained in analyzing materials of this character is alone a valuable return for the outlay of time and money expended in their preparation. A new form of mixer for metal samples has been devised and has been tried out with success in most cases.

Nearly 9,000 tests were made by this division during the past year, which is a very large increase over the work of the previous years. This increase is mainly due to the demand on the part of the Government departments for tests to determine whether or not deliveries of materials and apparatus conformed to the specifications upon which they were purchased, and to assuming the testing work formerly done in other Government laboratories. By far the greater number of these tests were made for the Government—3,221 being made for the Supervising Architect's Office; 2,454 for the Isthmian Canal Commission; 2,021 for the Government Printing Office; 794 for the General Supply Committee; and a lesser number for 19 other branches of the Government service and for States, municipalities, universities, and private parties. Of these, 2,774 were of irons, steels, and other metals; 712 of cements; 298 of asphalts, coal tars, etc.; 1,852 of paints and paint material; 35 of waxes; 121 of rubber; 2,950 for papers, pens, inks, typewriter ribbons, of which 2,571 were for papers; and more than 100 miscellaneous items. Many of these materials require an average of about 12 determinations per sample.

In view of the fact that the Bureau has increased to a considerable extent the chemical examination of structural materials, the character of the examination required upon these materials will be described briefly.

The asphaltic materials and felts are used in building construction on foundations and roofs as a waterproof medium. They are examined to determine their specific gravity, general character at various temperatures, loss in weight on heating and effect of such heating, per cent soluble in various organic solvents, amount of ash, etc. The roofing felts are also examined to determine the amount of felts and saturation matter and percentage of wool and cotton fiber in the felt. These tests give a general indication of the character and origin of the materials and their probable value as waterproofing mediums.

Cements are tested to determine their specific gravity, fineness of grinding, time of setting, soundness in air, water, and steam, and tensile strength neat and when mixed as mortar with standard sand. In addition to the above physical tests, complete chemical analyses are made on practically all the samples submitted. The information obtained from such tests determines whether the materials meet the prescribed specifications and indicates their general quality. The tests are, however, inadequate to determine fully the quality of the material, and no truly satisfactory tests have as yet been developed for this purpose.

Terneplate is sheet iron or steel coated with an alloy of lead and tin, and is used in metal roofing. It is tested to determine the weight per square foot, the amount and composition of the coating, and the

black plate to which the coating is applied is analyzed to determine its general character. The galvanized sheets are examined in a similar manner, to determine the amount and character of coating and character of base.

Most of the ferrous metals are samples of various grades of steel and iron submitted by the Isthmian Canal Commission. They include not only different grades of structural steel but also various steels used in locomotive and car construction and special alloy steels.

The nonferrous metals cover a wide range of brasses, bronzes, white metal alloys, etc., used by the Isthmian Canal Commission for fittings, bearings, etc.

Most of the paint materials are submitted by the Supervising Architect's Office, for use in the public buildings being erected by that office. The oil driers are examined to determine the amount of oil and volatile matter present, the amount and character of metallic oxides used as the drying agents, the character of the volatile matter, and the actual drying effect of a fixed amount of the driers with standard linseed oils and turpentines. The linseed oils are tested for purity by determining certain constants, as specific gravity, iodine absorption, saponification value, acid value, flash point, etc. Limiting values have been set for these constants, and linseed oils to be considered pure must come within these limits. The amount of pigment, oil, and volatile matter is determined in the paints and the character and composition of each is then determined. The time of drying and character of the film are also determined.

The oil varnishes are examined to determine approximately (no accurate method having been developed) the amount of oil, gum, and volatile matter they contain. The acid value and the ash, showing what oxides have been used as driers, are also determined. The volatile matter is tested for boiling point, specific gravity, action of concentrated sulphuric acid, etc., to determine the presence and amount of petroleum products and turpentine. Further tests are also made to detect the presence of rosin. The spirit varnishes are examined in a similar manner to determine the amount of gum and volatile matter and their character.

In addition to this routine examination of Government purchases, there is a constant attempt to improve the method of analysis in each case, so as to furnish additional information regarding the character and quality of the materials tested.

The results of this work will be of great value in the development of improved specifications by a comparison of laboratory records with the behavior of the material under service conditions.

Special laboratory tests, also, have to be developed to produce in a relatively short time the same effect as long-time service exposure. In this line a program has been outlined covering an investigation

of the value of various materials used as waterproofing, damp proofing, and roofing coatings. This will include exposure of these materials to normal and abnormal conditions of service, with physical and chemical laboratory tests, and the study of the data thus obtained.

ENGINEERING INSTRUMENTS.

The work of the engineering instrument section has consisted chiefly of the rating of water-current meters for the Geological Survey, Reclamation Service, and the State water resources offices, and the development of methods for the testing of speed-measuring instruments, such as speedometers, tachometers, and taximeters. A careful study has been made of practically all the various types of speedometers at present on the market and the results are now ready for publication.

At the request of the General Supply Committee, a preliminary study was made of two types of fire extinguishers submitted by them and many extinguishers now in service in the departments were examined. This work has been reported to the committee and at their request is to be continued.

Among the instruments calibrated during the year are 162 water-current meters, 38 pressure gages, 13 speedometers, 4 fire extinguishers, 2 anemometers, and 2 gasometers.

STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

STRUCTURAL MATERIALS.

The number of routine tests of structural materials made during the year was approximately double the combined tests of a similar nature made by the Geological Survey and the Bureau of Standards during the preceding fiscal year. This was made possible by reorganizing and improving the routine methods. The results thus far attained indicate that the Bureau will be of material aid to the industries concerned particularly by the standardization of apparatus and methods of testing.

At the beginning of the year the testing and investigation of structural materials by the Bureau was augmented by the work of that nature formerly conducted by the United States Geological Survey, and the laboratories, equipment, and personnel for this work were formally transferred. Previous to this time the work was carried on by the Geological Survey in four laboratories—one in Pittsburgh, Pa., which conducted tests and investigations of ceramics, cements, lime, steel, and miscellaneous structural materials; one in Washington, which tested structural and miscellaneous materials, mainly for the Supervising Architect's Office; one at Northampton, Pa., for the testing of cement, principally for the Isthmian Canal Commission,

and one at Atlantic City, N. J., for conducting an investigation of the effect of sea water upon concretes and protective coatings.

The equipment transferred consisted of one 100,000-pound, three 200,000-pound, and one 600,000-pound testing machines, and a new 10,000,000-pound Olsen testing machine not then delivered by the maker, as well as various smaller machines for testing cement and clay products, together with miscellaneous laboratory apparatus for this work, and office furniture.

The testing work and investigations in progress at the time of the transfer were continued, but some changes were made in the arrangement of the laboratories and distribution of the work. The work of the Washington laboratory was moved to the Bureau of Standards buildings as soon as the necessary laboratory space could be equipped with facilities for the work.

While the testing was not disturbed by the transfer, it was necessary to devote considerable time to reorganizing the work and coordinating it with the similar established testing work of the Bureau. Much has been done in collating and preparing for publication the unpublished data accumulated prior to the transfer. This data consists of results of many investigations, of which some were started as early as 1906. Practically all of the results of these tests were uncollated and considerable time was required for verification, calculation, study, and preparation of the manuscripts. The following reports have been prepared for publication: "The Strength of Reinforced Concrete Beams—Results of Tests of 333 Beams (first series);" "Tests of the Absorptive and Permeable Properties of Portland Cement Mortars and Concretes, Together With Tests of Damp-proofing and Waterproofing Compounds and Materials;" "The Effect of High-Pressure Steam on the Crushing Strength of Portland Cement Mortar and Concrete;" and "Lime: Its Properties and Uses."

The investigation and testing of structural materials comprises both chemical and physical tests. The chemical work is in general done by the division of chemistry and is described elsewhere in this report. The more important of these materials are cements, ceramics, lime, metals, and protective coatings. The work on these materials will be discussed under their respective heads.

CEMENT.

Over 23,900 samples of cement, representing over 2,300,000 barrels, were tested at the Washington, Pittsburgh, Northampton, and Allentown laboratories. This required a total of over 521,000 physical tests, consisting of determinations of tensile strength, soundness, time of setting, specific gravity, and fineness. During the preceding year less than 12,700 samples were tested in the combined laboratories of the Geological Survey and Bureau of Standards.

Practically all tests were made for the Government departments, each laboratory inspecting and testing the cement purchased in its particular field. All cement used in the construction of Federal buildings throughout the country, and miscellaneous samples received from other Government departments and the public, were tested in Washington. Cement purchased in the vicinity of Pittsburgh, by the Navy and War Departments, was inspected at the mill and shipped under the supervision of the Pittsburgh laboratory. The cement for the Isthmian Canal was tested at Northampton, Pa. It was found expedient to establish also a temporary laboratory at Allentown, Pa., to take care of sampling at the mills and testing the cement purchased by the Navy and War Departments in that vicinity.

At the present time each branch of the Government is purchasing cement upon a different specification, although the same quantity of material is desired. In an endeavor to obtain one standard, engineers from all departments of the Government using cement were called into conference at the Bureau to consider the unification of existing cement specifications and the preparation of a single standard specification for use throughout the United States.

The investigation of the action of sea water on cements, mortars, and concretes was continued at the Atlantic City laboratory. The work done was somewhat in excess of that of the preceding year. The results so far obtained have been tabulated and studied and a preliminary report is in course of publication. Tests to determine the effect of alkali water on cement mortars and concretes were continued and practically completed.

A short series of tests was made at the Pittsburgh laboratory on the use of pulverized tufa and pulverized sand, to determine the effect of these on the strength of mortars when replacing part of the cement.

CERAMICS.

This work is largely conducted at the Pittsburgh laboratory, although some testing and investigative work is done in the Washington laboratory. During the year it was devoted to the testing of clays and clay products for various Government departments and making investigative tests for the public. Research was also conducted on the development of the toughness of burnt clay, representing typical materials. In connection with this work, sand-blast apparatus was designed and constructed, and data on the relative merits of the sand blast and rattler tests were obtained. The study of the relation between the porosity and crushing strength of burnt clay was pursued, and the work was almost completed. The study of different methods for determining the absorption, porosity, permeability, and specific gravity of building brick has been extended.

An investigation on the technical control of the colloid matter of clay was completed and the matter is being prepared for publication. An investigation of the effect of preliminary heat treatment upon the drying of clays was also completed and published during the year.

LIME.

This work has been carried on at the Pittsburgh laboratory. It consisted of the determination of the effect of the burning temperature of lime upon its properties, including porosity, specific gravity, rate of hydration, and content of carbon dioxide. Tests were also developed and instruments were designed for testing commercial limes. These tests are to be used in measuring the rate of hydration, plasticity, sand carrying capacity, color, yield, hardness, shrinkage, time of setting, and crushing and tensile strength. A calorimeter, slaking machine, and viscosimeter were designed and constructed. These tests were applied to a number of synthetic mixtures in order to determine the effect of impurities. The relative rate of carbonation of quick and hydrated lime was also measured. The effect of temperature, size of stone, and porosity on the rate of decomposition, was studied. Continuing the policy of keeping in close contact with plant operations, three lime plants were visited. As previously stated a circular was prepared and issued on the properties and uses of lime. There has been a very large demand for this circular from producers and users of lime.

METALS.

The testing and investigation of metals are conducted at both the Washington and Pittsburgh laboratories. Practically all of the tests were made for the Government, for the purpose of determining whether or not the material delivered complied with the specifications. This material consisted of structural steel members, angle bars, turn buckles, car couplers, chain triplets, wire ropes, iron and steel castings, bronzes, babbitts, metal roofing, galvanized sheets, various steels used in locomotive and car construction, special alloy steels, wire rope, white metal alloys, etc.

In extending the testing and investigation of metals, and permitting a practical application of the research work in the laboratory, strain measurements were made during the year on structures of magnitude, such as railway bridges of large span, the lofty types of architectural structures, and steam boilers under hydrostatic pressures. These strain measurements, taken in conjunction with the laboratory tests of the physical properties of the component parts of structures, give a complete history and record of the material for engineering purposes.

The strain measurements upon steam boilers indicate that it may be feasible to judge the efficiency of the material in the design of boilers of different types, by means of such measurements over the usual range of hydrostatic test pressures; that is, this system may enable rational rules and formulas to be developed governing the allowable steam pressures under which the boilers may be used. This information may be obtained upon boilers of current manufacture without in any way impairing their usefulness or subsequent service condition.

The strain measurements during the year comprised observations on the large structural members and main trusses of the Bankers' Trust Company building in New York City, on structural members of the New York City bridges, on members of the Pittsburgh and Lake Erie Railroad bridge over the Ohio River at Beaver, Pa., on the Missouri River Bridge at Kansas City, Mo., on steam boilers at Providence, R. I., and preparations are being made to begin this work on the massive lock gates of the Isthmian Canal.

PROTECTIVE COATINGS.

This material was tested by the Washington laboratory, mainly for the Supervising Architect's Office, and included asphalts and coal tars, felt, paint and paint materials, linseed oil, oil driers, varnishes, etc. As these tests are mainly chemical in their nature, these materials are treated more particularly under the heading of "Chemistry."

MISCELLANEOUS MATERIALS.

A large number of miscellaneous materials were tested for the Government departments, including rubber belting, rubber bands, packings, various types of hose, belting, belt lacing, etc. In many cases investigations have been made with a view to the preparation of standard specifications for these miscellaneous materials, and it has also been necessary to do considerable work in the development of methods of testing.

NEW TESTING MACHINES.

The installation of the two Emery testing machines in the Washington laboratory is practically complete so far as pertains to the machines proper. The work is in an advanced state on the weighing mechanism of each machine. These machines will be provided with an improved type of hydraulic accumulator, and it is believed that with the completion of this equipment the Bureau will be provided with testing apparatus superior to any other in existence.

At the Pittsburgh laboratory a new building is being erected for the housing of the 10,000,000-pound Olsen testing machine. This is

the most powerful testing machine which has been constructed. It is of the vertical type and is especially adapted to the testing of large masonry columns. For the handling of large specimens, the testing machine is being provided with the necessary traveling cranes and other hoisting facilities. The Pittsburgh laboratory also has a vertical testing machine of 600,000 pounds capacity and several types of commercial testing machines. The two laboratories will be well adapted for making investigative tests on the physical properties of structural materials of all classes.

PAPER AND TEXTILES.

The testing of papers, textiles, and cordage has extended to practically every department of the Government.

Assistance has been rendered numerous State and city governments in selecting standard papers, and analyses have been made for dealers and manufacturers.

The equipment for extending paper investigation and preparing experimental papers has been supplemented and some preliminary work accomplished.

The equipment for the conditioning of textile materials has been nearly completed. Some investigation has been made of the accuracy obtainable in the determination of yarn counts both in the yarn and finished fabric. A study of the experimental sampling, scouring, and conditioning of wool is in progress and has already yielded some interesting results.

There were tested 3,276 papers, 1,207 samples of cordage, and 606 textiles. It has rendered extensive assistance to the General Supply Committee in the preparation of specifications, the testing of samples, and in expert service on its several subcommittees in the making of awards.

It has also assisted committees of Congress, the President's Commission on Economy and Efficiency, the Tariff Board, and several departments in the collection of technical data.

THE OFFICE.

LIBRARY.

The library contains 7,528 accessioned volumes (including a few bound pamphlets), almost exclusively of a scientific and technical character. During the year the Library of Congress has transferred to the Bureau the second copies of books deposited for copyright, bearing on physics, testing of materials, and allied subjects, in all 560 volumes. The Library of Congress and other libraries have freely loaned books to the Bureau as in previous years. The number of periodicals currently received has been 270, most of them being obtained through exchange with the Bulletin of the Bureau.

PUBLICATIONS.

During the year 29 new scientific papers were published, giving results of investigations conducted by the Bureau. Eleven revised editions of circulars were printed, and 6 new circulars issued upon the following subjects: "The Standardization of Bomb Calorimeters," "Publications of the Bureau of Standards," "The Testing and Properties of Optical Instruments," "The Determination of the Optical Properties of Materials," "Announcement of a Change in the Value of the International Volt," and "Lime: Its Properties and Uses."

The results of technologic investigations are being prepared for publication in a new series of publications, to be called "Technologic Papers of the Bureau of Standards." The first number of this series is entitled "Effect of Preliminary Heating Treatment on the Drying of Clays."

PERSONNEL.

The personnel of the Bureau, including the Director, as provided by Congress, for the past fiscal year, consisted of 192 persons, classified as follows:

Laboratory: 1 chief physicist, 1 chief chemist, 2 associate chemists, 2 physicists, 12 associate physicists, 32 assistant physicists, 7 assistant chemists, 38 laboratory assistants, 15 aids, 12 laboratory apprentices, and 3 laboratory helpers; total, 125.

Office: 1 secretary, 1 storekeeper, 1 librarian, 14 clerks, 1 packer and shipper, 5 messenger boys; total, 23.

Operation of plant: 1 superintendent of mechanical plant, 4 assistant engineers, 2 electricians, 3 firemen, 3 watchmen, 1 messenger, 5 skilled laborers, 4 laborers, 3 janitors, 2 female laborers, 1 telephone operator, 1 elevator boy; total, 30.

Construction: 1 chief mechanician, 8 mechanicians, 2 skilled woodworkers, 1 draftsman, 1 glass blower; total, 13.

In addition to the foregoing, approximately 77 persons have been employed in special research and other work, being paid from the appropriations provided by Congress for conducting these investigations. The number of the employees engaged in this class of work varies from time to time in accordance with the needs of the service.

SUMMARY OF TESTS.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. A certain amount of this work is already organized upon an accurate routine basis. Much of it, however, involves investigation of the scientific principles underlying the test, a study of existing methods, and the development of new standard tests of known accuracy. In

such cases, the research which must precede the actual testing is a most important function of the Bureau. For the test a reasonable fee is charged, except when made for the National or State governments. The corresponding amounts for Government testing are of interest, however, and are added to the statement of tests which follows:

NUMBER AND VALUE OF TESTS COMPLETED, FISCAL YEAR ENDED JUNE 30, 1911.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length	179	$586.45	132	$353.80	311	$940.25
Mass	2,884	1,347.40	816	377.70	3,700	1,725.10
Capacity	7,334	2,497.45	337	321.05	7,671	2,818.50
Temperature	3,392	1,119.63	15,834	3,463.29	19,226	4,582.92
Hydrometry	2,339	2,355.00	103	169.25	2,442	2,524.25
Miscellaneous	217	426.00	5	9.00	222	435.00
Optical	1,314	1,343.50	23	39.20	1,337	1,382.70
Electrical	149	1,008.55	362	1,759.25	511	2,767.80
Photometry[1]	3,612	8,569.00	308	1,178.70	3,920	9,747.70
Chemical[2]	9,907	33,297.75	126	2,582.94	10,033	35,880.69
Physical and mechanical tests:						
Engineering (miscellaneous)	2,316	2,501.25	232	157.00	2,548	2,658.25
Engineering instruments	192	872.00	26	108.50	218	980.50
Structural materials	24,350	46,599.08	93	454.00	24,443	47,053.08
Paper and textiles	3,384	6,134.50	133	160.79	3,517	6,295.29
Total	61,569	108,657.56	18,530	11,134.47	80,099	119,792.03

[1] Besides the foregoing, the Bureau inspected 942,059 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $6,674.75 additional.
[2] 3,314 tests, amounting to $23,738.61, were chemical tests made on structural materials.

The number of tests made for the Government during the fiscal year 1911, exclusive of lamps inspected at factory, was 173 per cent greater than in the preceding year, and the number of tests for the public was 52 per cent greater, the increase in tests for both Government and public amounting to 154 per cent.

The receipts for tests were as follows:

Total receipts, 1911		$10,880.73
Received prior to July 1, 1910, for tests completed in fiscal year 1911	$200.43	
Outstanding fees	387.64	
Refunds	8.04	
		596.11
		11,476.84
Received for tests completed, fiscal year 1910	136.00	
Received for tests in progress at close of fiscal year 1911	206.37	
		342.37
Fee for tests completed, fiscal year 1911		11,134.47

FINANCIAL STATEMENT.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1911, the disbursement during the year, the amount of unfilled and unpaid

orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1911:

Appropriation.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$201,440.00	$181,406.84	$8,153.43	$11,879.73
Equipment	46,000.00	38,364.18	7,476.75	159.07
General expenses	19,000.00	17,616.36	1,175.04	208.60
Grounds	3,000.00	2,192.65	614,88	192.47
Laboratory (continued)	175,000.00	174,720.01	70.00	209.99
Investigating effects of electric currents	15,000.00	11,587.65	3,361.71	50.64
Testing machine (continued)	180,000.00	135,883.88	43,901.88	214.24
Testing structural materials	50,000.00	44,308.14	5,544.62	147.24
Weights and measures	10,000.00	7,466.59	1,839.18	694.23
Testing of structural materials of the United States	15,000.00	15,000.00	.....	.....
Testing machine at Pittsburgh, Pa	25,000.00	146.00	.....	24,854.00
Total	739,440.00	628,692.30	72,137.49	38,610.21

The following statement shows the condition of the appropriations for the preceding two fiscal years at the close of business June 30, 1911:

Appropriation.	1909				1910			
	Total appropriation.	Disbursement.	Liability.	Balance.	Total appropriation.	Disbursement.	Liability.	Balance.
Salaries	$141,540.00	$138,765.11	.....	$2,774.89	$165,280.00	$160,455.01	.....	$4,824.99
Equipment	41,000.00	40,906.27	.....	93.73	46,000.00	44,149.27	$1,780.07	70.66
General expenses	15,000.00	14,097.20	$4.00	898.80	17,500.00	17,200.70	230.71	68.59
Grounds	3,000.00	2,997.22	.....	2.78	3,000.00	2,963.63	.....	36.37
Gaslight standards	.....	.....	.....	.....	10,000.00	9,951.36	13.74	34.90
Weights and measures	.....	.....	.....	.....	10,000.00	7,633.82	.....	2,366.18
Freight truck	.....	.....	.....	.....	4,000.00	4,000.00	.....	.....
Total	200,540.00	196,765.80	4.00	3,770.20	255,780.00	246,353.79	2,024.52	7,401.69

Respectfully,

S. W. STRATTON, *Director.*

To Hon. CHARLES NAGEL,
Secretary of Commerce and Labor.

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